

HCAT PROGRESS REPORT SEPTEMBER 2002

STATUS

CONDUCTING THREE TESTS:

1. Fatigue of entire MLG - Dash-8 Series 400.
2. High Cycle (Dithering) wear test on hydraulic actuator.
3. Fatigue of MLG pistons 5" and 10" OD (Cr vs. WC-Co-Cr).

HVOF coating is WC-Co-Cr.

Report Documentation Page				Form Approved OMB No. 0704-0188	
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TEST 1: MLG FATIGUE TEST

CURRENT STATUS

- 14 parts have been HVOF coated (piston, axle, and pins).
- Components sprayed by Vac Aero and Southwest Aeroservice.
- Gear has been assembled, installed in the test rig and testing has begun.

TEST 1: MLG FATIGUE TEST

CURRENT STATUS

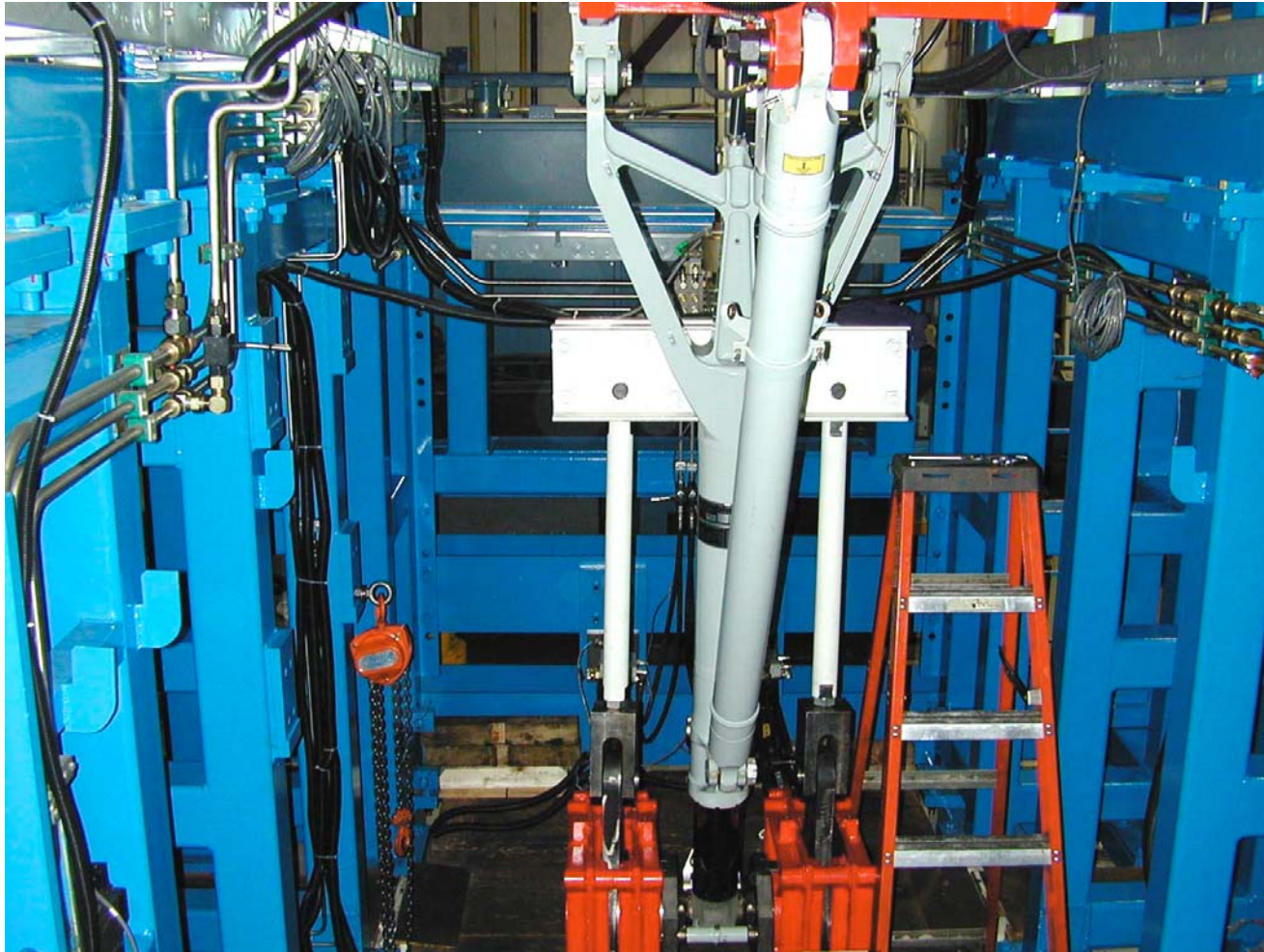
- Testing - 10 layers of testing = 5 lives.
- Each layer includes 32 blocks of test conditions (load location, magnitude, direction and number of cycles).
- 1 layer of fatigue consists of 30 blocks of ground load conditions (= 30,000 flight cycles), 1 block of retraction lug test conditions (66,000 gear extend and 33,000 gear retract flight cycles) and 1 block of stabilizer brace lock link test conditions (99,000 lock and 33,000 unlock flight cycles).

TEST 1: MLG FATIGUE TEST

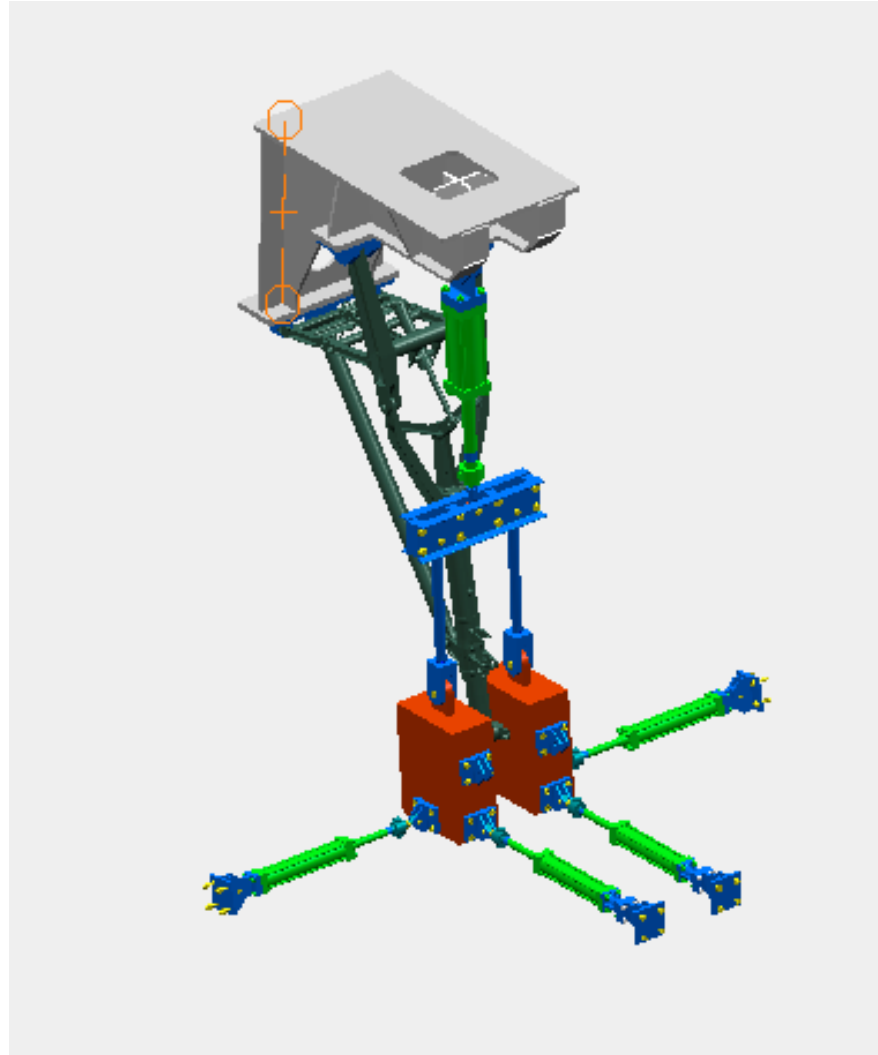
CURRENT STATUS

- Testing considered successful when the gear withstands 5 lives of fatigue loads without initiation of detectable fatigue cracks. 1st life inspection revealed no issues.
- Test has accrued 1.24 lives (~25% complete). Some delays with the test rig and changing seals.
- Testing began with elastomeric T-type seals but the seals failed after 330,000 cycles.
- Second type of elastomeric seal failed after 480,000 cycles. New Seal Design has recently been installed.

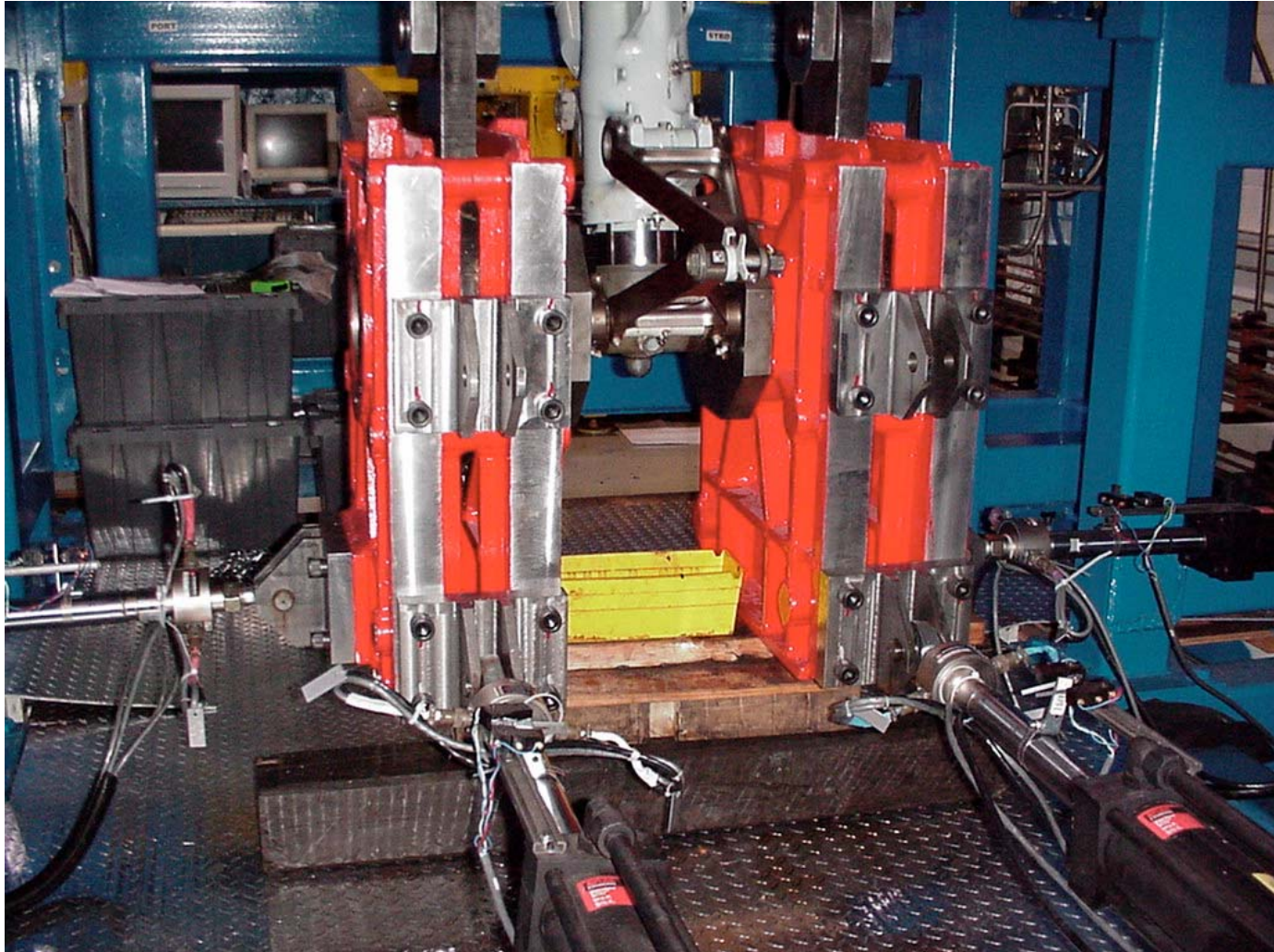
TEST 1: MLG FATIGUE TEST



TEST 1: MLG FATIGUE TEST



TEST 1: MLG FATIGUE TEST



TEST 2: HIGH CYCLE WEAR TEST

CURRENT STATUS

- Purpose: Testing performance of HVOF coating on an aircraft actuator and demonstrate it can withstand constant cycles under endurance stress level for a civil aircraft actuator.
- 3 actuators being tested, 2 chrome plated, 1 WC-Co-Cr coated.
- Chrome finished 8-16 Ra.
- HVOF finished 3 Ra.

TEST 2: HIGH CYCLE WEAR TEST

CURRENT STATUS

- Test program is approximately 95% complete.
- To date scheduled inspections have found the HVOF coating acceptable with no evidence of scratches, cracks or other unacceptable indications.
- No evidence of leakage or wear on the seals.

TEST 2: HIGH CYCLE WEAR TEST



TEST 3: PISTON FATIGUE TEST

CURRENT STATUS

- First test: 5" OD Piston (3 Cr and 3 HVOF) - simulate a commercial regional aircraft.
- Second test: 10" OD Piston (3 Cr and 3 HVOF) - simulate large commercial jet.

TEST 3: PISTON FATIGUE TEST

SCOPE OF TEST

- Purpose: “...to compare the fatigue performance of simulated LG piston coated with HVOF applied WC-Co-Cr and electrolytic chrome plating.”
- “This test is aimed at deriving fatigue life design factors...”
- “The test will be performed until failure of the simulated LG pistons occurs.”

SCOPE OF TEST WAS ALTERED FOR 3rd HVOF 5” PISTON

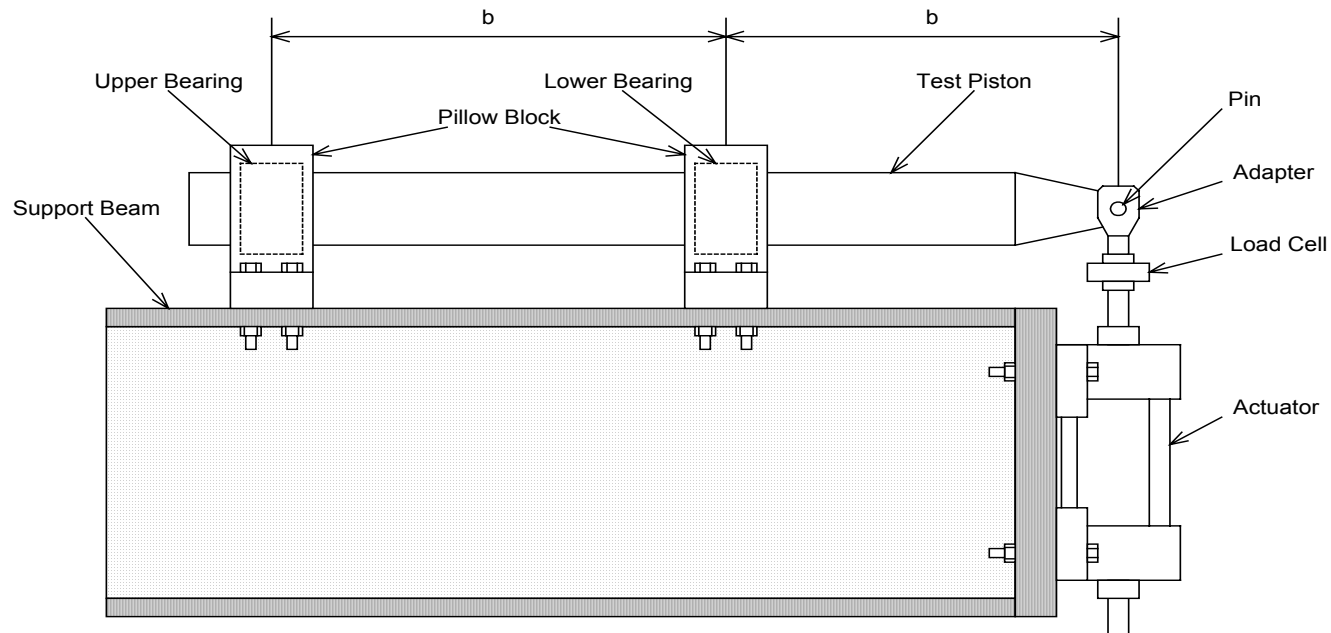
TEST 3: PISTON FATIGUE TEST

Test Conditions

- Bending loads based on fatigue analysis and landing gear fatigue requirements.
- Bending stresses approx. 100 ksi at $R = -1$.
- 50,000 cycles = 1 block of tests. Inspection after every block.
- Expected lives: 285,000 for 5" pistons, 330,000 for 10" pistons.

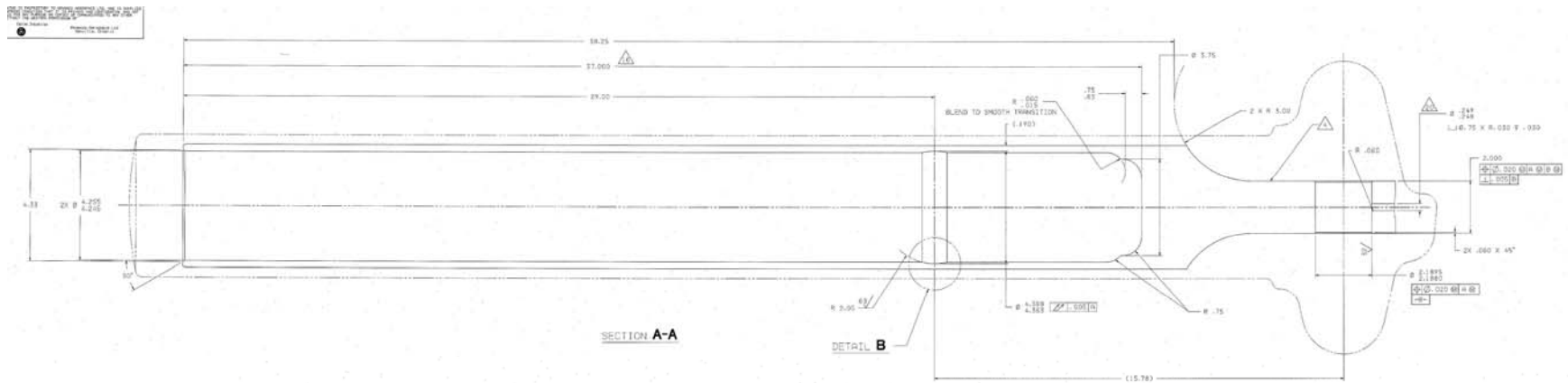
TEST 3: PISTON FATIGUE TEST

TEST CONFIGURATION



TEST 3: PISTON FATIGUE TEST

TEST SPECIMEN CONFIGURATION



TEST 3: PISTON FATIGUE TEST



TEST 3: PISTON FATIGUE TEST



TEST 3: PISTON FATIGUE TEST



TEST 3: PISTON FATIGUE TEST

CURRENT STATUS

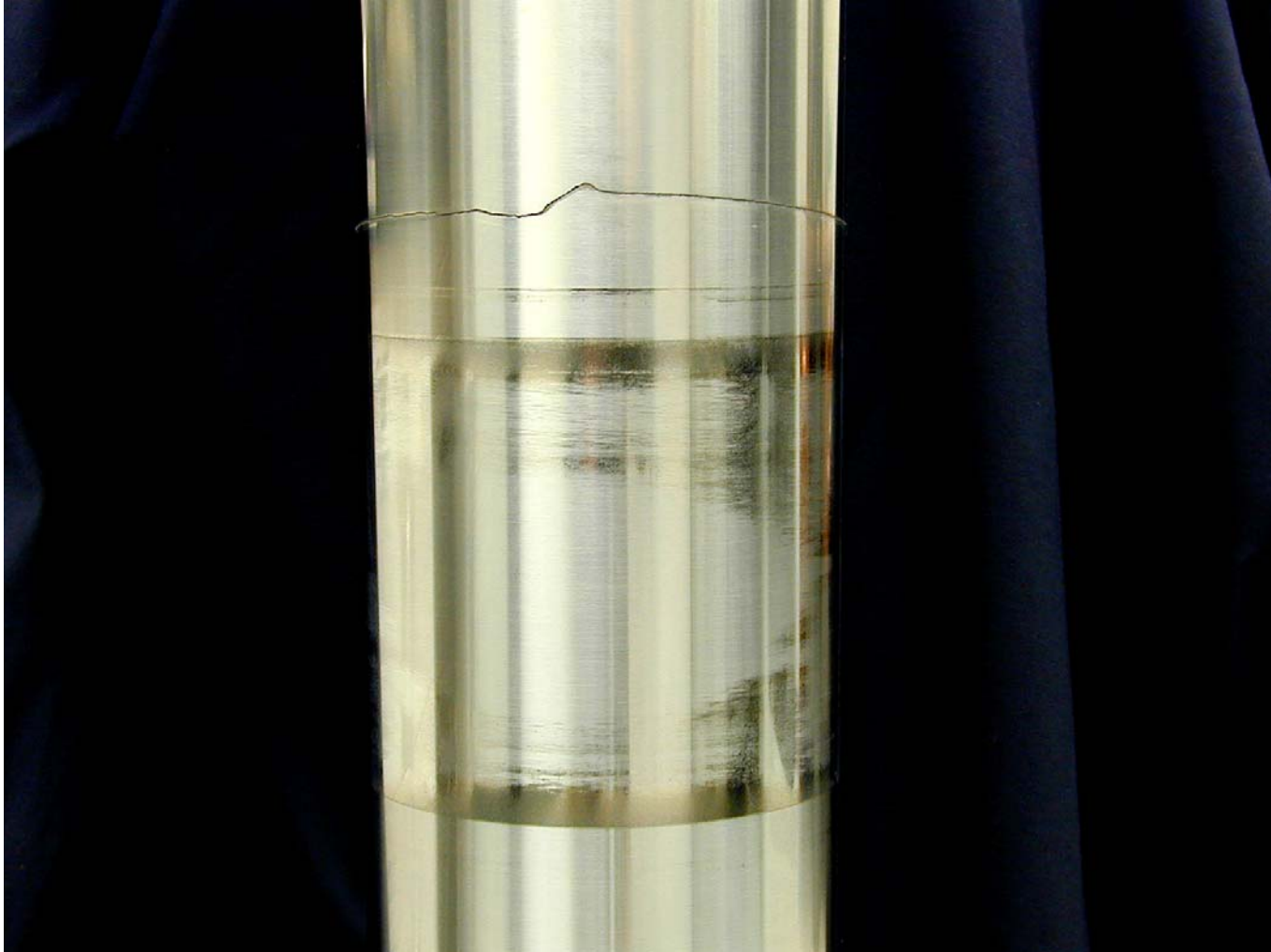
- 5" OD pistons have been HVOF sprayed (Vac Aero), ground and superfinished to 4 Ra by Goodrich (with assistance from Jon Devereaux, US Navy).
- Chrome plated pistons were processed in-house by Goodrich. Finished to better than 16 Ra.
- 10" OD pistons are complete, but not HVOF coated.

TEST 3: PISTON FATIGUE TEST

TEST RESULTS

- **1st chrome plated piston:**
285,000 + 122,000 cycles. ~100ksi at notch
- No spalling of coating prior to failure. Some surface wear noted on chrome plating.
- **Piston failed at notch.**
Crack initiated near the piston inner diameter at an **inclusion** - extended circumferentially outward.

TEST 3: PISTON FATIGUE TEST



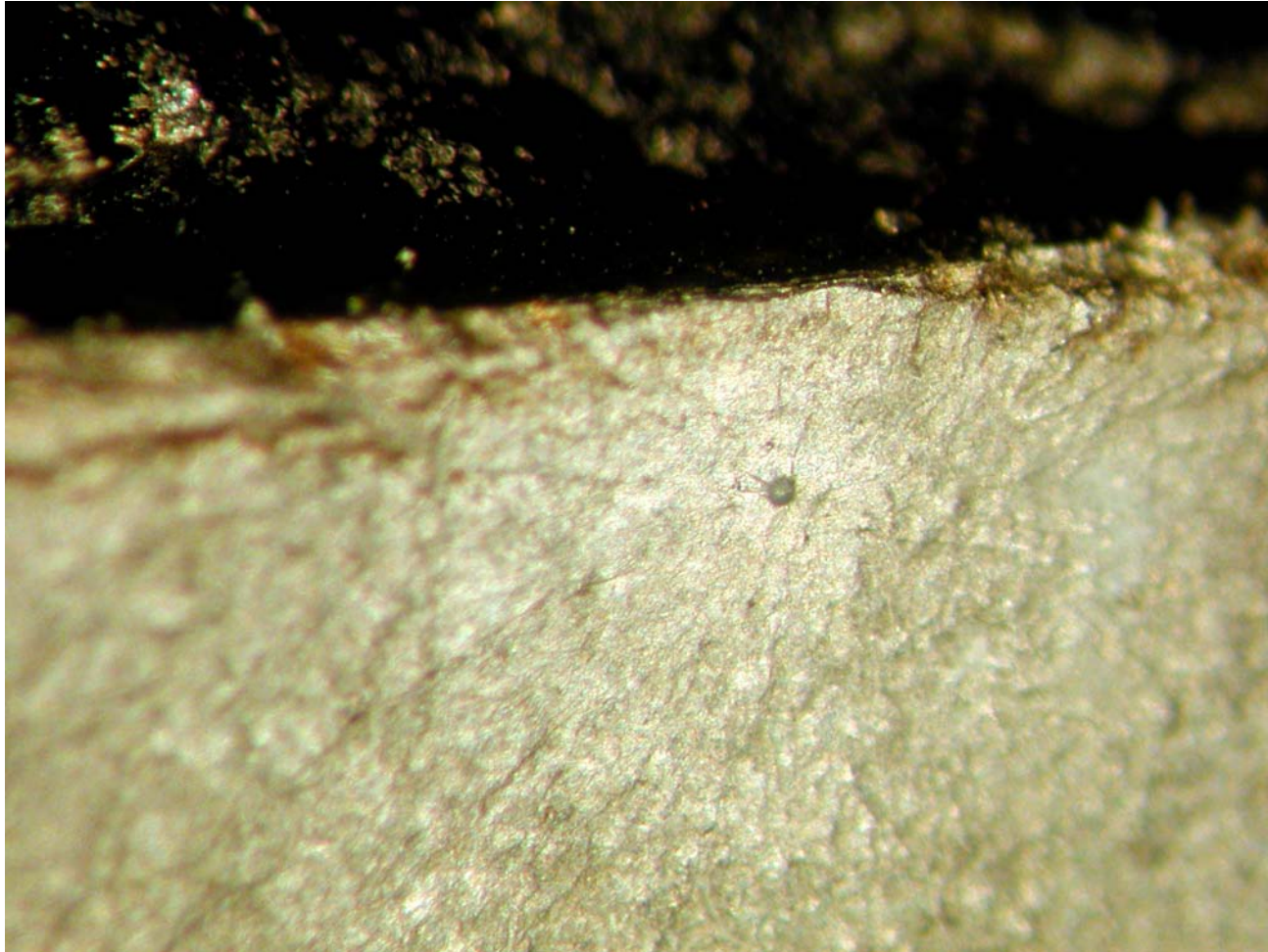
CHROME PLATED 5 INCH PISTON

TEST 3: PISTON FATIGUE TEST



CHROME PLATED 5 INCH PISTON

TEST 3: PISTON FATIGUE TEST



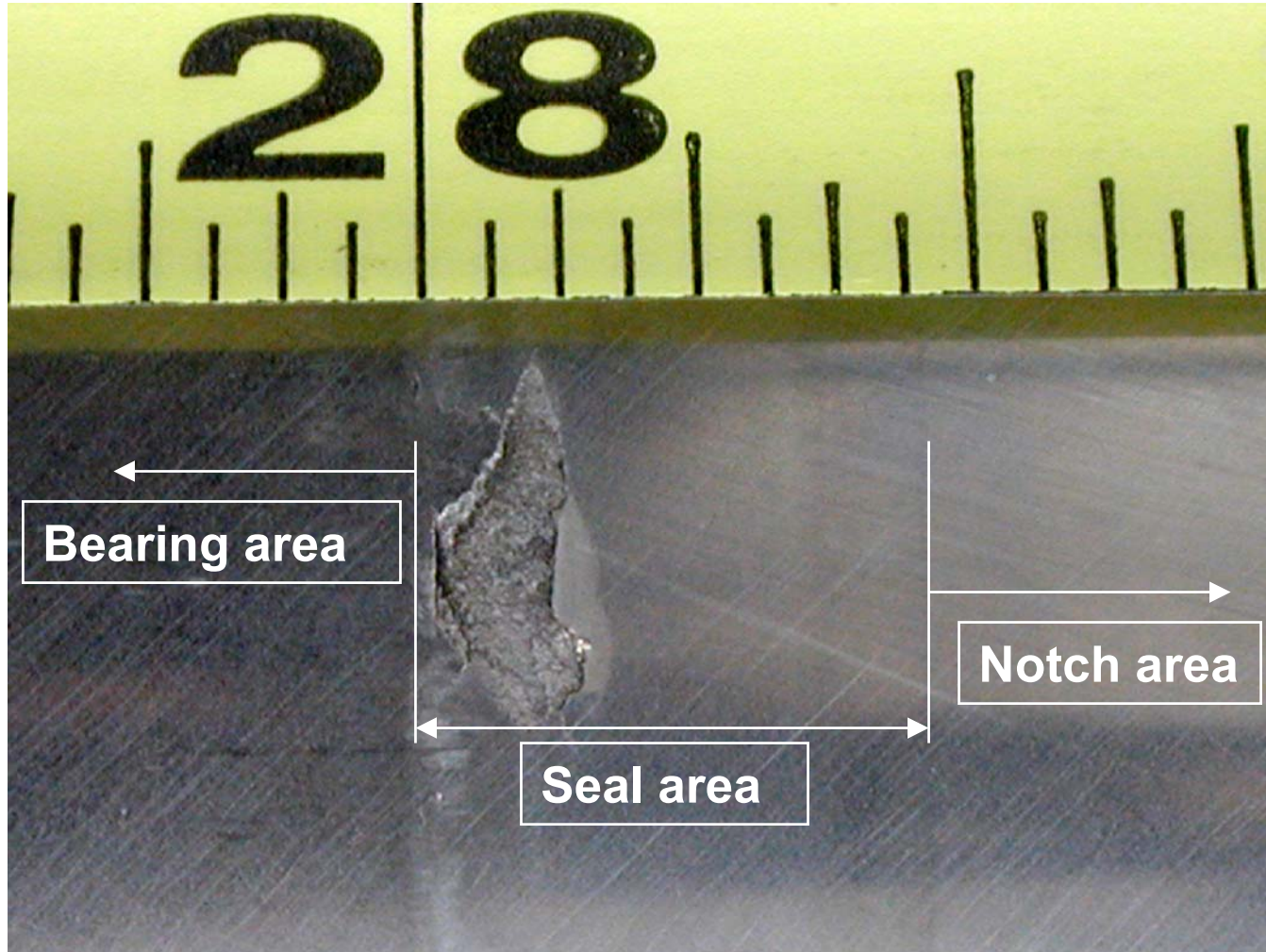
CHROME PLATED 5 INCH PISTON

PISTON FATIGUE TEST

TEST RESULTS

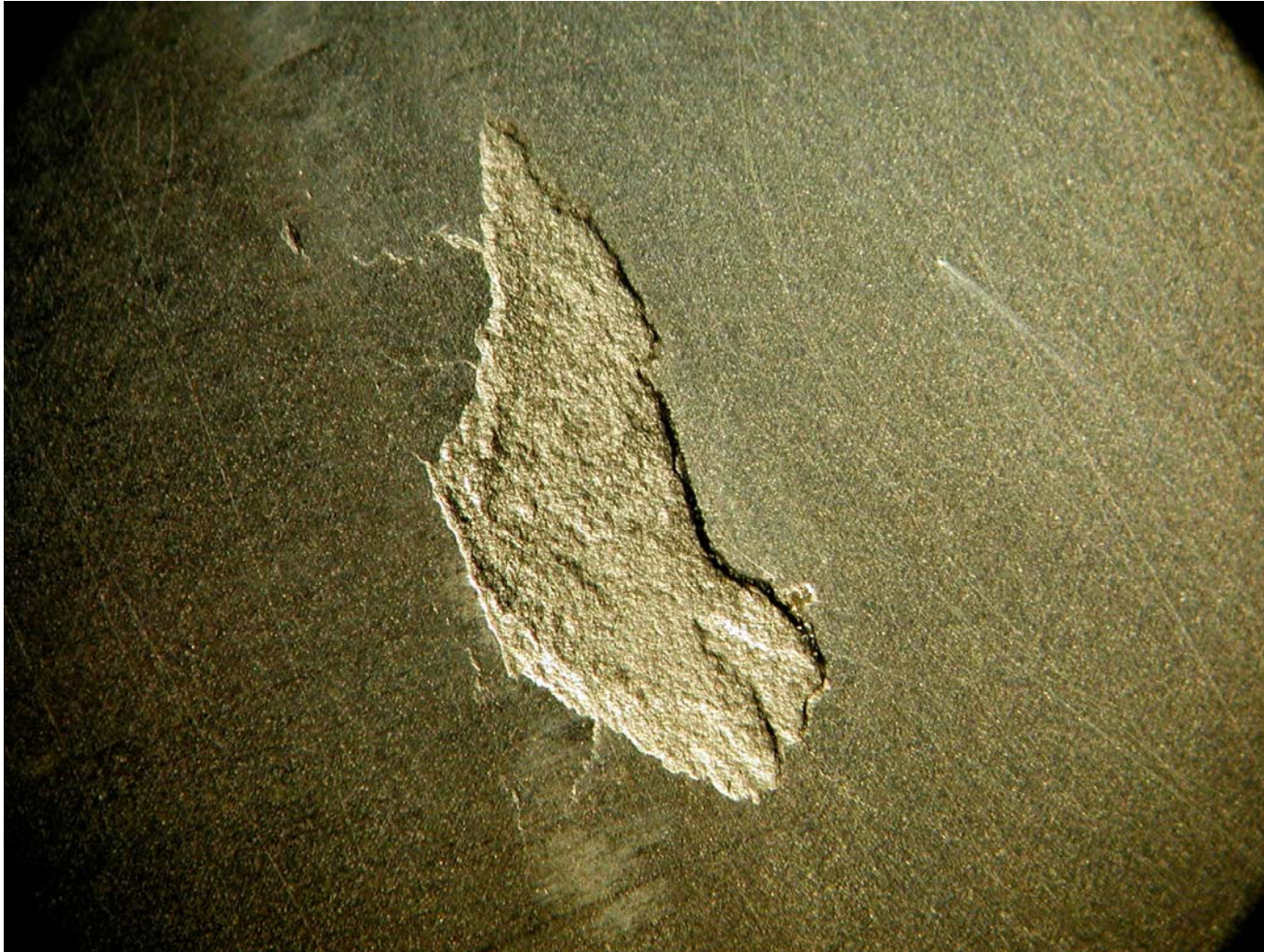
- **1st HVOF coated piston:**
570,000 cycles, i.e. 2 lives, ~ 100ksi at notch
184,500 cycles, ~ 110ksi
- Small area of failed coating (approximately .150" x .350"), between 250,000 - 285,000 cycles at bottom.
- Visual, MPI, LPI and Barkhausen Noise inspection after 570,000 cycles did not find evidence of substrate cracking.
- **Piston failed at bearing contact point**

TEST 3: PISTON FATIGUE TEST



HVOF COATING AFTER 285,000 CYCLES

TEST 3: PISTON FATIGUE TEST



HVOF COATING AFTER 285,000 CYCLES

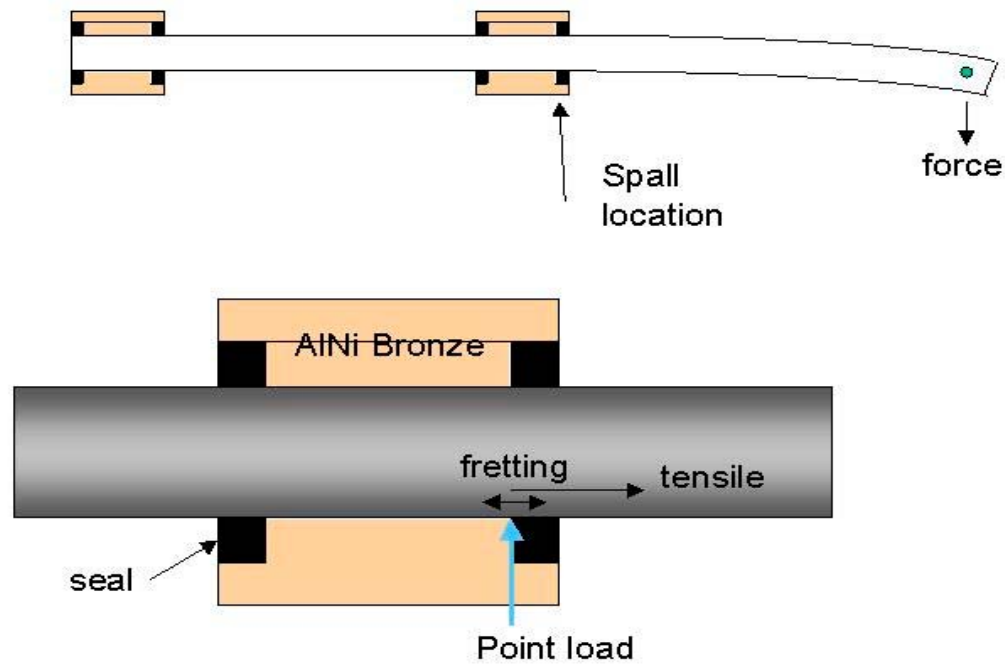
TEST 3: PISTON FATIGUE TEST



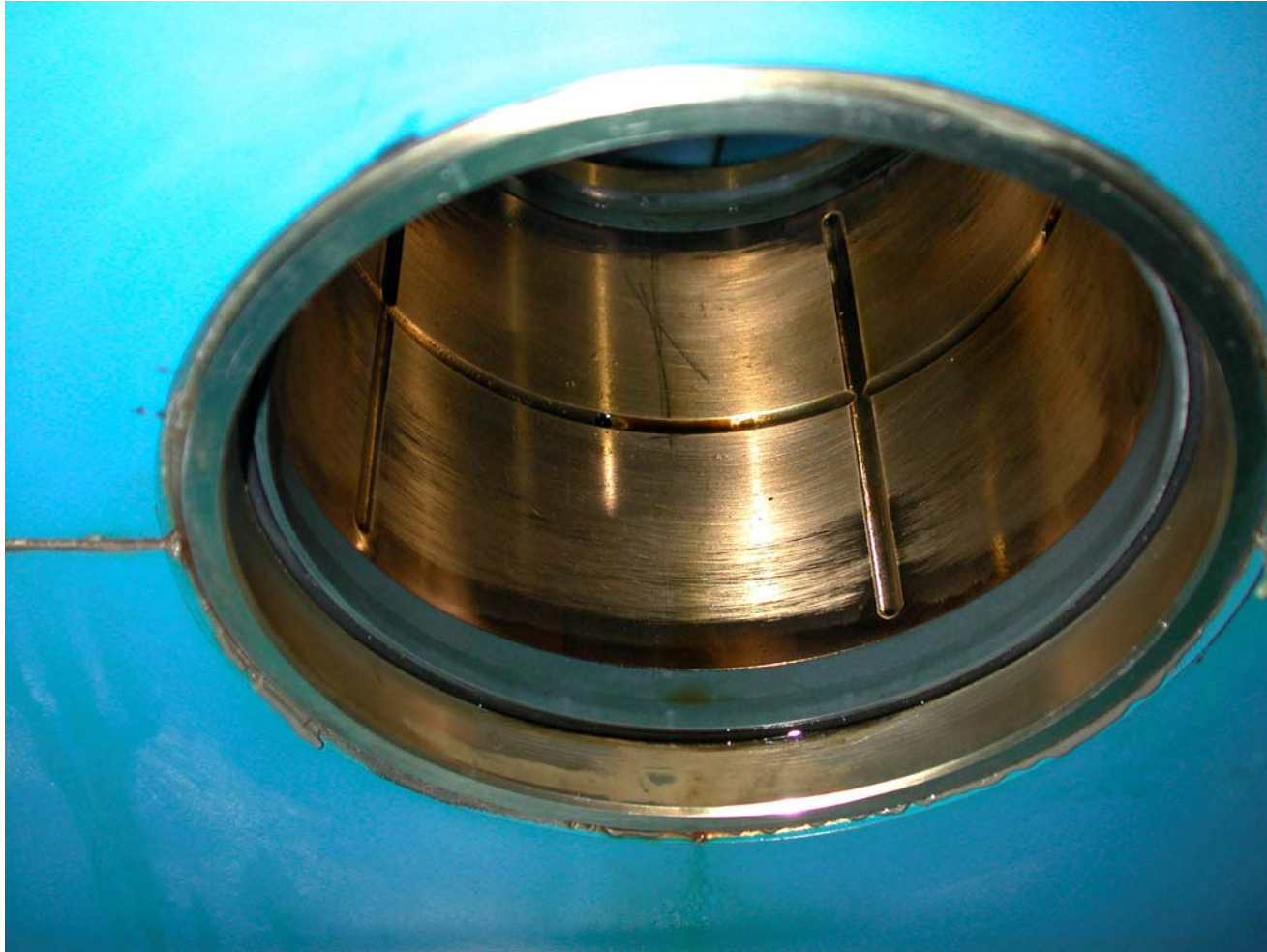
HVOF COATING AFTER 570,00 CYCLES

TEST 3: PISTON FATIGUE TEST

Bend test setup



TEST 3: PISTON FATIGUE TEST



BUSHING CONFIGURATION

TEST 3: PISTON FATIGUE TEST

TEST RESULTS

- **2nd Chrome plated piston:**
1,000,000 cycles. ~110ksi at notch
20,000 cycles. ~135ksi at notch

- **Piston failed at notch**

- **3rd Chrome plated piston:**
62,000 cycles. ~125ksi at notch

- **Piston failed at notch**

TEST 3: PISTON FATIGUE TEST

TEST RESULTS

- **2nd HVOF coated piston:**
33,000 cycles. ~125ksi at notch
- **Piston failed at bearing contact point, large area of coating failure 2"x0.25"- top and bottom**

SCOPE OF TEST ALTERED

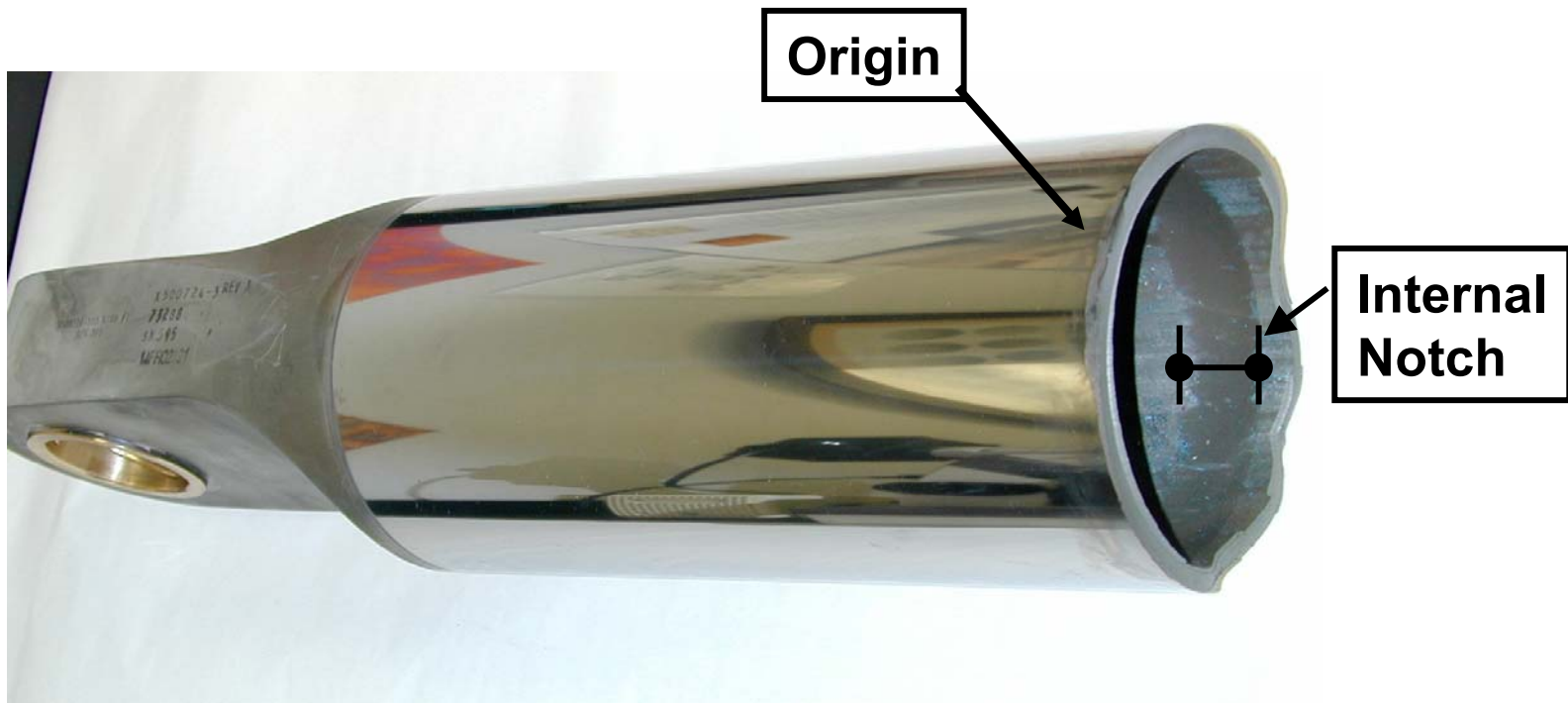
Coating Application? (different coating supplier)

Understanding of coating failure mechanism

Comparison of LG spectrum to test conditions

TEST 3: PISTON FATIGUE TEST

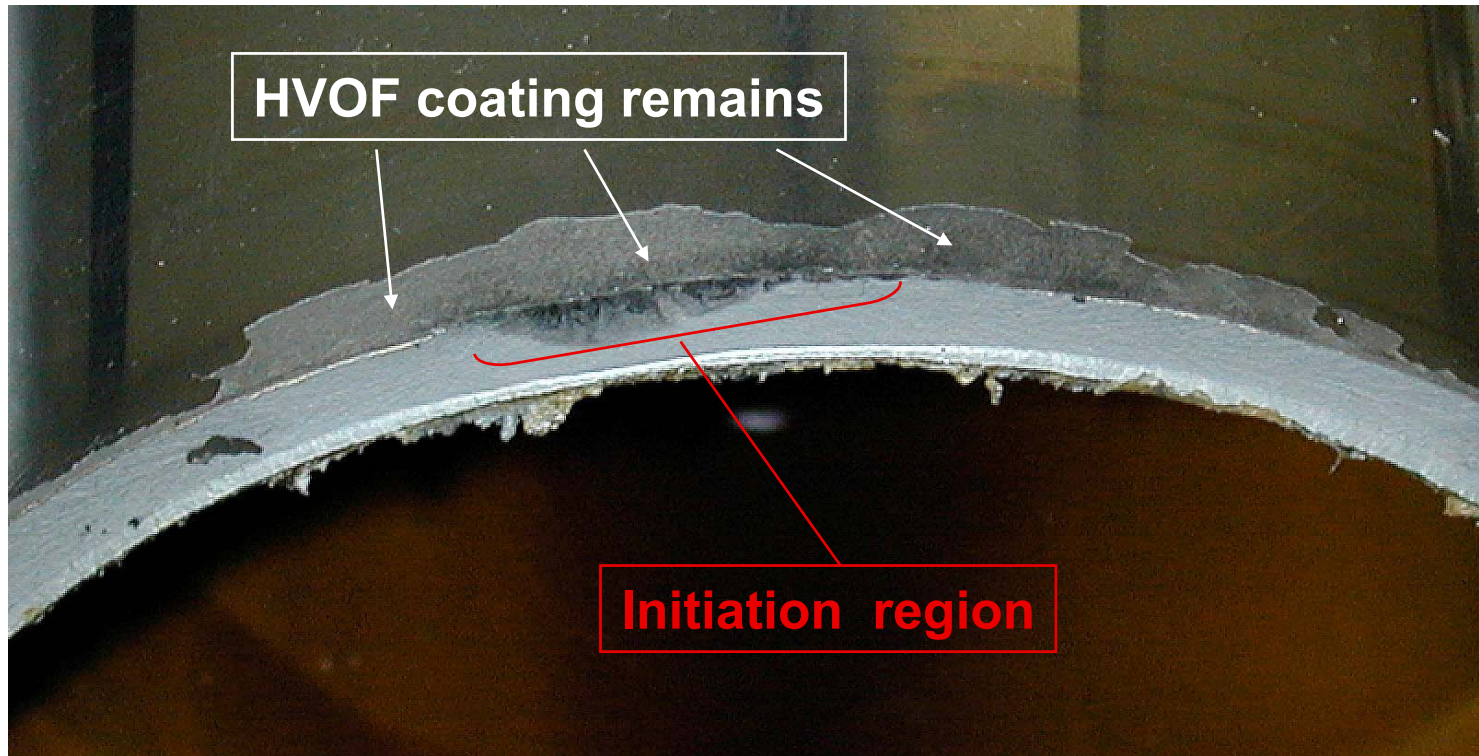
TEST RESULTS



2nd HVOF coated specimen

TEST 3: PISTON FATIGUE TEST

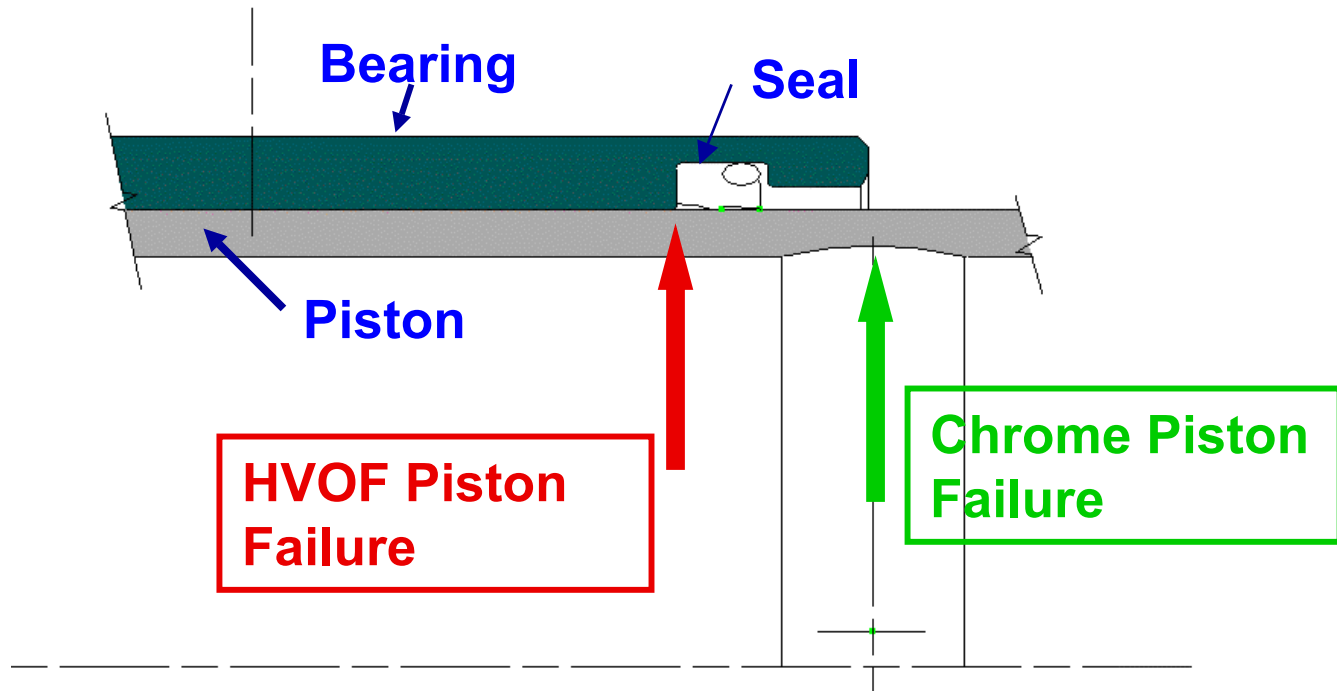
TEST RESULTS



2nd HVOF coated specimen

TEST 3: PISTON FATIGUE TEST

TEST RESULTS



TEST 3: PISTON FATIGUE TEST

TEST RESULTS

➤ **3rd HVOF piston, coated by SouthWest Aero :**

2,000 cycles ~125 ksi

5,000 cycles - some cracking top and bottom

10,000 cycles - significant circumferential cracking

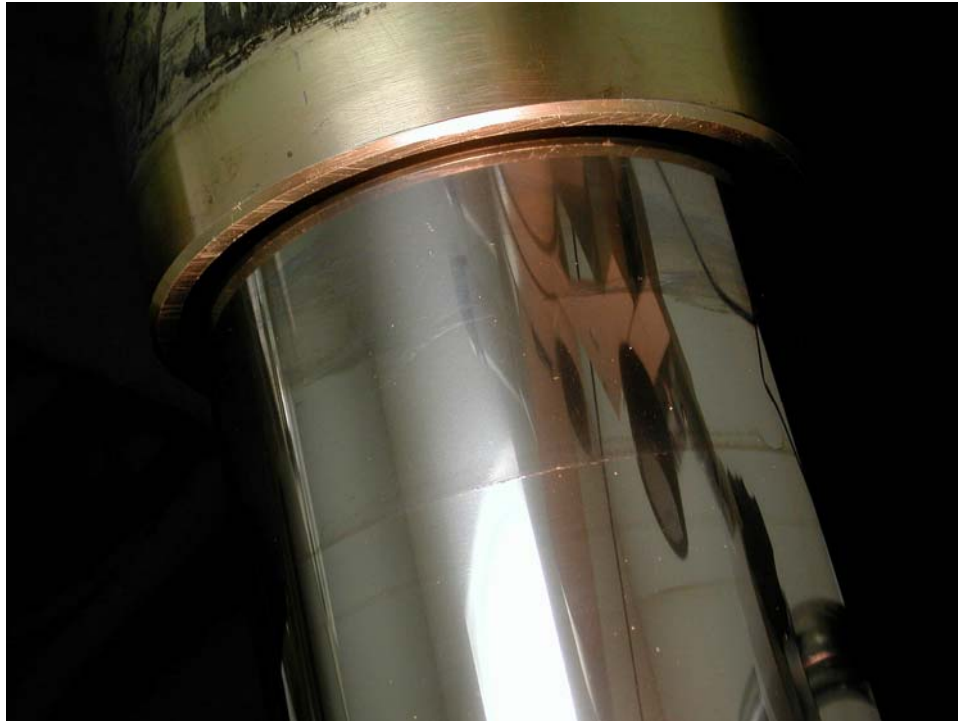
15,000 cycles - coating separation evident

20,000 cycles - coating blistering 2" x 0.15"

25,300 cycles - failure at the bearing contact point
initiating at bottom

TEST 3: PISTON FATIGUE TEST

TEST RESULTS



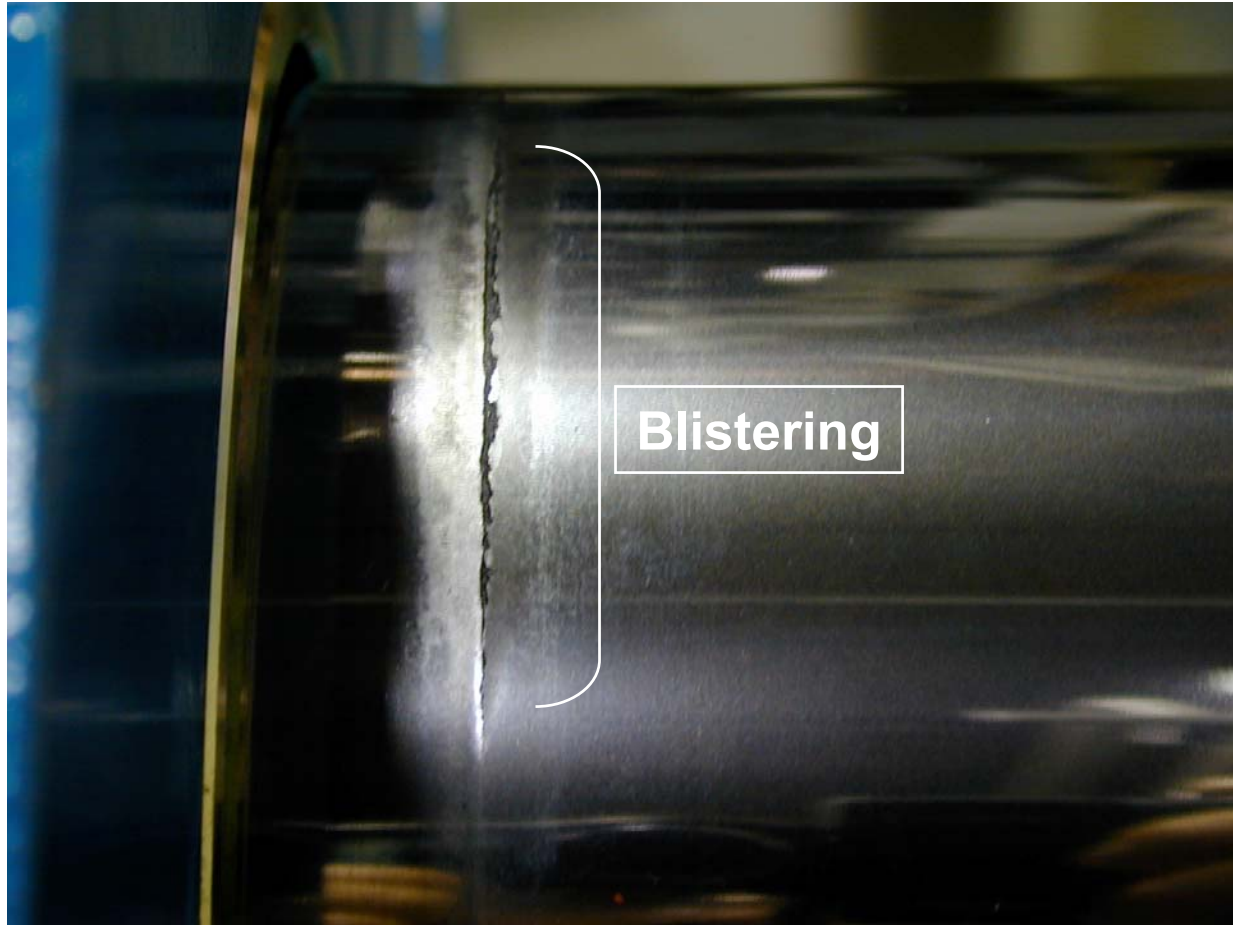
X~10

←→
Bearing area

Appearance of coating after 10,000 cycles

TEST 3: PISTON FATIGUE TEST

TEST RESULTS



Appearance of coating after 25,000 cycles

TEST 3: PISTON FATIGUE TEST

SUMMARY

Piston	Stress (bending)	Cycles	Failure Mode
1st Cr	100 ksi	407K	ID, @ notch (inclusion)
2nd Cr	110 ksi	1M	
	135 ksi	20k	ID, @ notch
3rd Cr	125 ksi	62K	ID, @ notch
1st HVOF	100 ksi	570k	coating failed (250K)
	110ksi	185K	OD, @ bearing
2nd HVOF	125 ksi	33K	OD, @ bearing
3rd HVOF	125 ksi	25K	OD, @ bearing

SUMMARY

- **HVOF pistons failed at contact point with bearing - Failure originated at OD; Chrome plated pistons failed at notch - Failure originated at ID.**
- **Cracking of coating is circumferential, localized and appears to occur relatively early ~5 K cycles @125ksi**
- **Coating failure is cohesive (substrate still coated).**
- **Coating application and finish - not a factor.**
- **Commercial Landing Gear Stresses are comparable to test - but # of cycles much smaller.**
 - **LG spectrum 125 ksi -- 575 cycles/5 lives (120 one life)**
 - **Test regime 125 ksi -- 5,000 - 7,000 cycles**
- **Test conditions too severe, not representative of LG.**

FUTURE ACTIONS

Test conditions too severe, not representative of LG.

- 1) Rigid bearing reaction**
- 2) Single stroke position**
- 3) Monotonic cycling**

Scope of test changed to simulate LG conditions - 10" test

- 10" Rig will be re-designed to represent LG lower bearing**
- Simple spectrum loading will be implemented**
- Representative bearing will be implemented**

